

## 4 Solar System, Planet Sizes

Most toy models of the solar system, and most of the mobiles you can buy to hang in your room, do not give you any information on how they made them or why they are made the size they are. They may be beautiful to look at and the colors may be correct, but which of their other physical characteristics are correct and which are incorrect?

In the following exercise, we are going to explore one physical characteristic, namely size. We are going to do this by making 3-D models of the planets that will have the same size relationship as the real planets.

### 4.1 Making Planets<sup>4</sup>

To make our planets, we are going to follow a recipe. Like any good recipe, small “mistakes” while we are making our planets will not matter very much in the end, but the closer we can follow the recipe, the more accurate our final result will be.

#### Recipe for One Solar System

##### Includes One Dwarf Planet

1. Divide your dough into 10 equal-sized parts. Place 6 parts in the pile for Jupiter, 3 parts in the pile for Saturn, and keep the last part.
2. Divide the remaining dough into 10 equal-sized parts. Place 5 in the pile for Saturn. 2 in the pile for Neptune, 2 in the pile for Uranus, and keep the last part.
3. Divide the remaining dough into 10 equal-sized parts. Place 5 in the pile for Neptune, 4 in the pile for Uranus, and keep the last part.
4. Divide the remaining dough into 10 equal-sized parts. Place 3 in the pile for Venus, 4 in the pile for Earth, and combine the other 3 for the next step.
5. Divide the remaining dough into 10 equal-sized parts. Place 2 in the pile for Venus, 1 in the pile for Earth, 2 in the pile for Mars, 4 in the pile for Uranus, and keep the last part.
6. Divide the remaining dough into 10 equal-sized parts. Place 8 in the pile for Mercury, 1 in the pile for Uranus, and keep the last part.
7. Your last part is Pluto. Actually, if you were *very* careful and followed the recipe exactly, it is too big by about 8%.

Our planet model (recipe) will focus on only one physical characteristic of the planets: size, or more specifically, volume. Why volume? When we look glasses of water (or juice, or soda), we instinctively judge the size of the glass by its volume.

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4 This exercise originally came from *Family Astro*, a set of activities published by the Astronomical Society of the Pacific, <http://www.astro.society.org/>. It has been slightly modified based on data from <http://www.nineplanets.org/>.

Our judgment isn't perfect; sometimes we can be fooled by oddly shaped containers. Usually, we can tell which of two containers hold more. And how much it holds is a measure of its volume. But if you look at most astronomy text books, they will tell you the planet diameters, not the volumes. While those numbers are correct, they may not give us quite the right impression as to how large the planets really are.

Of course, there is more to a planet than just volume. Other physical characteristics include its temperature and composition, or how fast it is spinning (how long is its day), how strong is its magnetic field, is its rotational axis tilted like Earth's? Planetary scientists (the kind of astronomer who specializes in the planets) study those and more.

## 4.2 How Big?

Here's an activity just for fun. How many Plutos could you fit inside each of the other planets? In Table 4 I show the volume data for the 8 planets and Pluto.

Planet	Radius (km)	Radius as a Fraction of Jupiter's	Volume (billions of cubic km)	Number of Plutos
Mercury	2440	3.4%	61	10
Venus	6052	8.5%	929	146
Earth	6378	8.9%	1087	171
Mars	3397	4.8%	164	26
Jupiter	71492	100.0%	1530597	240259
Saturn	60268	84.3%	916957	143935
Uranus	25559	35.8%	69939	10978
Neptune	24766	34.6%	63629	9988
Pluto	1150	1.6%	6	1

*Table 4: Planet Sizes*

You can fit a lot of Plutos inside Jupiter! You might find it fun to use your calculator how many Earths you can fit inside Neptune, Uranus, Saturn, and Jupiter.

## 4.3 Here Comes the Sun

We didn't include the Sun in our model, and for a very good reason. It's huge! The Sun's radius is 699,500 km, about 109 times the radius of the Earth, almost 10 times the radius of Jupiter. With our play dough models of the solar system, Jupiter came out about 6 inches, the Sun would need to be 60 inches (5 feet) to be to scale.

Here's to more fun calculations to put everything into perspective: If we use our play dough scale, how far away would we have to put the planets? Our "map" scale is 5 feet equals 699,500 kilometers, so Pluto, at 5,914,000,000 kilometers away works out to be 4,227 feet away, about 8/10 of a mile or about 1.3 kilometers!

## 4.4 Home Activities

### 4.4.1 Moon Phases

On Halloween, I was able to catch the moon as a very thin crescent low in the south just after sunset. If you were out at the party in Owl's Head Park, where I was, you might have seen it, too.

Continue the Moon phases chart. Next week we are going to combine all of our records and develop a model for the moon's changing appearance.

### 4.4.2 Size: Length, Area, Volume

When we say that one object is twice as big as another, what exactly do we mean? If I live on 70<sup>th</sup> Street, then I can say that 76<sup>th</sup> Street is twice as far as 73<sup>rd</sup> Street and it is obvious that I mean length (distance). But if I say my dining room is twice as large as my kitchen, do I mean the length of one wall (or both walls), or do I mean the floor area? We have to carefully describe what it is that we are comparing.

When you read a book about the size of the planets, you will sometimes read that Jupiter is about 10 or 11 times bigger than Earth. Other times, you will read that it is over 1000 times bigger! Which is correct. It turns out that the problem is just what we were describing in the first paragraph: the different authors were using different things to compare size.

In order to explore the relationship between length, area, and volume, do the following exercises. You will need a few sheets of "graph paper" which can be found in local drug stores as "quadrille ruled" paper. The grid of lines will make the exercises much easier. Each of the little "boxes" formed by the grid will let you measure length and area just by counting.

1. Use a sheet of graph paper (quadrille-ruled paper) to make a square which has four "boxes" on each side. How many boxes are included inside the square? What happens to the area if you double the length of both sides? What happens to the area if you triple the length of both sides?
2. Use a compass to draw a small circle with a diameter of 4-6 boxes. Estimate the area inside the circle by counting the boxes. Boxes that are completely inside count as one, those which are at least half inside count as one, and those which are less than half inside do not count. What happens to the area if you double the diameter of the circle? What happens to the area if you triple the diameter of the circle?
3. How are the changes in the area of the circle and the changes in the area of the square similar or different?
4. Use some play dough or modeling clay to make a small cube. Measure the length of each side with a ruler to make sure they are close to the same (it will probably be impossible to get them exactly the same, just make them as close as you can). You can calculate the volume of the cube as (length) x (width) x (height). Of course, those three values should be the same, so this is the same as (length) x (length) x (length). Whenever we multiple a number

by itself like this, we call it cubing, so we would call this (length)-cubed.

Turn your cube into a sphere by rolling it carefully until it is as round as you can make it. Your sphere has the same volume as the original cube since you didn't add or take away any clay. Measure the sphere's diameter. If you find it really hard to measure with a ruler, try taking a piece of thread, fishing line, or nylon picture hanging line to cut your sphere in half right through the center. Then you can measure the diameter much more easily.

Repeat this for different sized cubes (add some clay and make the cube, then the sphere). Can you find a relationship between the volume and the diameter (or radius) of the sphere?

## 4.5 Resources

- The Astronomical Society of the Pacific (<http://www.astrosociety.org/>) has literature and lesson plans for astronomical activities.
- The steps in our recipe were derived from data at <http://www.nineplanets.org/>, although it is hard even for them to keep up.